

# THE LOCATION AND REMOVAL OF MISSILES FROM THE CRANIAL CAVITY.

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## I. THE LOCATION OF MISSILES IN THE CRANIAL CAVITY.

THE traumatism of the bullet differs from that arising from any other cause, for the reason that, no matter how slight and apparently simple the injury, the element of concussion always enters into the case, and is to be added to the other existing symptoms. It is impossible to have a bullet injury without this added condition. Further, the concussion caused by fire-arm injuries of the head presents a much greater degree of intensity than can possibly be produced by any other means. The mere fact that the bullet strikes the head is sufficient to give rise to concussion ; it need not enter the head or even produce appreciable injury to the cerebral mass. The immediate effects of even spent balls are those of concussion.

The primary symptoms of bullet traumatism, therefore, are those of general shock communicated to the nervous elements. This occurs irrespective of the particular part involved, and independently of the nature and extent of the injury.

The immediate effects of all bullet injuries of the skull, no matter what part of the skull is struck or brain injured, are manifested upon the medulla oblongata. Even without penetration of the skull or injury to the brain substance, in the concussion which follows the pneumogastric centre and the respiratory centre are at once inhibited or absolutely paralyzed. Those parts of the brain that have well-known localizing functions fail

to give any evidence of their specific functions until the general signs of concussion have passed off.

This extraordinarily rapid suspension of the function of the respiratory centre is peculiar to gunshot injuries of the head. Its occurrence in connection with any other form of trauma is exceptional. The sudden failure of respiration in cases in which this occurs in comparatively slight injuries and in severe injuries in which the medulla is not directly or palpably injured cannot be explained in any other way.

It may be said in passing that there is reason to believe that the prompt application of artificial respiration may restore those functions that are so stupefied, so to speak, as to be incompetent to act intelligently, and that no person should be pronounced dead from a bullet injury to the head, other things being equal, unless artificial respiration has been tried and failed.

To sum up the symptoms which distinguish fire-arm injuries of the head from all other forms of traumatism, these may be stated to be as follows :

(1), The extraordinary rapidity with which the function of the respiratory centre in the medulla oblongata is inhibited or fails altogether. In the latter case the suspension of activity of the centre is like that of an engine caught "on the centre," from which point it cannot go on without assistance. This is supplied by artificial respiration, which may be successful, even after long intervals.

(2) The obscuring of every symptom by the prominence of the bulbar signs.

Another effect of the influence of concussion upon the medulla relates to the heart's action, which may be either retarded, as in moderate concussion, in which case cerebral anæmia produced by active contraction of the vessels will be present; or accelerated, as in intense concussion caused by severe laceration of brain tissue, and accompanying cerebral hyperæmia from paralysis of the vessels and loss of vascular tone.

The secondary symptoms of gunshot wounds of the head are of so varied a character as to be misleading, and they may be positively absent, as shown by the following case admitted to my service at St. Mary's Hospital, Brooklyn :

K. S., aged thirty-two years, stood before a mirror, and, taking deliberate aim, shot herself in the left temple with a 44-calibre revolver, just on a line with the top of the ear and about half an inch in front of the latter. The ball passed entirely through the head. She was brought to the hospital twenty-four hours later, perfectly conscious, with the statement from competent witnesses that she had never lost consciousness. She never complained of pain, nor was there, up to the time of her death from encephalitis forty-eight hours afterwards, paralysis of any kind.

The first point to be determined by the surgeon, when called to a gunshot wound of the head, relates to the possibility, when a fracture is found but no evidence of perforation exists, of the ball having passed through the bone between a depressed fragment and the adjoining sound bone, the former springing back from its natural elasticity after the missile has passed into the cranial cavity. Surgeons are familiar with the classical case of Von Bergmann, in which but a mere fissure existed at the point of injury, yet on autopsy a projectile was found in the brain. This fallacy has been commented upon and cases reported by König, and by Assistant Surgeon Howard, United States Army. It is more likely to arise in connection with gunshot injuries to the vault than elsewhere. In a case of my own which entered St. Mary's Hospital, the patient, a would-be suicide, shot herself in the frontal region, one and a half inches to the right of the interparietal, and about two inches in front of the fronto-parietal suture. What at first glance seemed to be the entire bullet was found beneath the scalp in the occipital region, but close inspection revealed the fact that a portion of the lateral surface was missing. A more careful examination of the point at which the ball struck the bone resulted in the discovery of two obliquely diverging fissures, with but a slight depression of the bone between. The trephine was applied just posteriorly to the point of junction of the fissures, and the missing portion of the missile was found, together with an attached portion of the internal table, embedded in the brain substance, within the area of opening furnished by an inch trephine. Other splinters from the internal table were also found, some of which bore lead markings.

Another fallacy consists in the existence of an opening of exit in cases of complete penetration, and still further emphasizes the importance of a close inspection of the bullet when it is recovered. In this connection an interesting case is reported by Lamphear.<sup>1</sup>

A man received a pistol-shot wound of the head, the ball striking one and a half inches to the right of the interparietal suture and about two inches posterior to the fronto-parietal suture. A wound of exit was found at the interparietal suture, the longitudinal sinus being injured in the passage of the bullet. The patient died, and the cause of death was found at the autopsy to be a cerebral abscess in the left cerebrum, just above the corpus callosum. The missing fragment of the bullet had passed through the right hemisphere, piercing the falx cerebri. The abscess was located at the point where the bullet was found.

Still greater difficulties may be encountered where the bullet enters from the direction of the cavity of the mouth. Here an immediate search should be made of the vault of the skull for projecting areas of the surface, or evidences of fracture. In this connection an interesting case is related by Gemans.<sup>2</sup>

A man, aged seventy-seven years, shot himself in the mouth, the bullet coursing upward and lodging just to the left of the median line, behind the fronto-parietal suture, where it produced a stellate fracture and bulging of the bone, plainly to be felt beneath the scalp. An incision was made and the fragments of bone together with the bullet removed. Walker<sup>3</sup> relates the case of a man shot in the mouth, in whom the wound of entrance was found to the left of the median line, behind the hard palate. A puffy swelling was discovered on the top of the head, through which a fracture could be made out. The scalp was turned back at this point, the fractured bone removed, and the bullet found lying beneath some blood-clot and lacerated brain substance.

If no bulging nor other evidences of fracture of vault are

<sup>1</sup> Kansas City Medical Index, August, 1888.

<sup>2</sup> Pacific Medical Journal, April, 1890.

<sup>3</sup> British Medical Journal, March 12, 1892.

obtained, the surgeon will next turn his attention to the possibility of the bullet having lodged in the nasal fossa or one of the accessory sinuses. An interesting case of this kind was admitted to my service at St. Mary's Hospital, in which the patient had placed the muzzle of a small revolver against the hard palate, the bullet lodging in the right nasal fossa, from which it was removed.

The ball may glance off from the bony structures of the base of the skull, or at the back of the pharynx, and lodge finally in the cavity of the mouth, or pass into either the œsophagus and be swallowed, or through the glottic opening, and enter either the larynx, trachea, or even the bronchi. In the first instance the patient may either spit it out or swallow it; if the latter, as well as when it passes down the œsophagus, it may be passed per rectum. Lodgement in the larynx will give rise at once to symptoms of suffocation, and necessitate immediate tracheotomy. If the ball passes beyond the larynx, if not of too large calibre, it will probably, by force of gravity, if its projectile force be spent, finally reach the bifurcation and lodge in one of the bronchi. The angle at which the left bronchus is placed to the trachea will favor its passage in that direction. When the ball reaches the cavity of the mouth by perforating the facial region, broken portions of the alveolar processes, together with detached teeth, may find their way in either of the directions indicated, and yet the bullet itself pass through the base of the skull.

The fallacy arising from the simultaneous reception of other injuries, which subsequently give rise to symptoms of cerebral disturbance, should not be lost sight of. In this connection the following case is of interest :

E. W., aged thirty-two years, was admitted to St. Mary's Hospital, November 30, 1894, with the following history : From early life he had been a "hard case." When a mere boy he was the leader of the "Cherry Hill Gang," and later in life he became one of the most dangerous and expert thieves in New York, attaining the title among his fellows and the police as the "prince of the light-fingered gentry." He was active in the pursuit of his calling until Tuesday afternoon, November 7, 1891, when, in a saloon brawl over election

returns, he was shot in the head. The fight was general, but the evidence seems to be pretty clear that W. was lying upon his back with his back looking towards his assailant when the shot was fired. The bullet went through the malar bone at its prominence. The hæmorrhage was profuse, and an ambulance was summoned, which took him to the Chambers Street Hospital, where he arrived about 6.30 in the evening. He walked up-stairs unaided and undressed himself. At this time his breathing was difficult and obstructive. This grew worse, and Dr. Stimson, hoping to recover the bullet as well as relieve his breathing, did a tracheotomy under an anæsthetic. Instead, however, of finding the bullet, the two back upper molars were removed from the trachea. The wound of the face and the track of the bullet were thoroughly explored by Dr. Stimson, but no trace of the missile could be found.

Upon the two days following he was very stupid; this was attributed to the combined effects of the alcohol, which he had imbibed, and the anæsthetic. Upon the third day, on awakening in the morning, and attempting to get out of bed, he found he had no power over the left side; he complained of difficulty of vision; in certain positions he saw double. No trouble with the bladder or rectum. When examined later in the day by Drs. Starr and Walter Vought he was found to be suffering from left hemiplegia and left facial paralysis. No definite localization of the bullet was made, although it was thought the latter was in or about the inner capsule.

He remained in the Chambers Street Hospital until January, 1892. With the exception of the lower extremity, which improved to the extent of permitting him to go about, there was no change in his symptoms. While it seemed certain that he was suffering from the presence of the bullet in the brain, yet no definite localization could be decided upon.

Six months afterwards (May, 1892) he presented himself at the Polyclinic, and was carefully examined by Dr. R. S. Newton, lecturer upon nervous diseases at that institution. He was then found to be suffering from left hemiplegia and left facial paralysis. There was likewise paralysis of the left sixth nerve, and in addition *loss of taste*. There were no sensory defects. In commenting upon the case at that time, Dr. Newton propounded the following questions:

(1) If the hemiplegia and facial paralysis were due to the same focal lesion, why did the former improve and leave the latter at a stand-still?

(2) Where in the brain could a lesion occur that would produce a hemiplegia combined with loss of taste?

(3) Was the combined loss of taste and sixth nerve paralysis to be taken as a sign of disease of the pons or base?

(4) Did the facial paralysis, loss of taste, and sixth nerve paralysis form part of the same process as the hemiplegia?

After careful study of the history and symptoms at this time, it was finally concluded by Dr. Newton that the facial paralysis was due to injury to the nerve, and that it had no connection with the hemiplegia, except in point of time; that the bullet entered the face, passed back, knocking out the teeth, and, meeting the temporal bone, became deflected, and passed across and up over the cavernous sinus to the clinoid process, where it cut out the sixth and seventh nerves. From here it had passed up into the white matter of the brain, and gave rise to the hemiplegia by pressure. Had the cortex been invaded, other symptoms, including convulsions, would have been present, which up to this time formed no part of the history of the case. Only in this way could be explained the loss of taste and the location of the bullet be removed from the pons or base.

One year later (May, 1893), he again came under Dr. Newton's observation. His face had improved in the meanwhile, so that he could close the left eye. The diplopia from the paralysis of the abducens had passed away. The paralyzed area had showed rigid contractions.

One extremely hot day in August, 1893, three months after the last observation and nearly two years following the injury, he was suddenly seized in Prospect Park, Brooklyn, with his first convulsion, for which he was taken to the Kings County Hospital. He was soon afterwards discharged. From this time until October, 1894, he had fourteen convulsions. These always began in the left arm and with movements of the globe, were accompanied by loss of consciousness, and were evidently cortical in origin. It now seemed apparent that the lesion had extended from the white matter to the cortex above, confirming the opinion previously held by Dr. Newton that the trouble causing the hemiplegia was in the motor convolutions, with facial, gustatory, and eye symptoms arising from injury, respectively of the trunks of the seventh (with its small filament to the lingual branch of the fifth) and the sixth or motor oculi externus, these being injured by the passage of the ball.

On December 24, 1894, he was placed under ether, and Dr.

Newton marked out upon the shaven scalp a space including the site of the top of the Rolandic area,—an experience in two previous cases in which the convulsions had been preceded by conjugate deviation of the eyes, leading him to believe the second frontal convolution, as well as the ascending frontal, to be involved, the area centre in these cases being placed higher up than the middle of the Rolandic area, and upon a plane with the leg centre in the posterior convolution. At about the middle of the area thus marked out, a small scar was now noticed for the first time, this showing the site of an old scalp wound. I turned back a U-shaped flap of scalp. Nothing abnormal in the exposed bone could be found. The trephine pin was placed as nearly as possible in the centre of the circle which had been marked out, and a one-inch button of bone removed. There was an absence of movements of the dura from cerebral pulsation, which at once attracted the attention of those present. Upon incising the dura a clear fluid escaped from a cyst cavity, the centre of which was located beneath the centre of the trephine opening. The capacity of this cavity was about a half ounce; it could easily accommodate a large English walnut. The cyst wall was smooth to the touch. An investigation of the neighborhood of the cyst was made by the finger palpating through the cyst wall. At one point, somewhat anteriorly and towards the median line, a point was felt which seemed more resistant to the touch of the finger in the cyst cavity. This was further explored by means of the telephone probe with a negative result.

As there was no tendency for the cyst wall to collapse, a small drain of iodoform wicking was passed to its most dependent portion and led out of the wound, the latter being closed except where the drain emerged.

Within forty-eight hours it was evident that the paralysis of the hand had improved; the sense of taste had returned. The drain was removed on the third day, and the scalp wound allowed to close. He persisted in visiting the water-closet for a movement of the bowels on the day following the operation. The course of the case was almost uneventful until the night of the ninth day, when, in spite of the application of a casing of plaster of Paris to provide against such a contingency, he removed this and the dressings to scratch his head. Upon the following day an erysipelatous blush appeared at a point where he had displaced the partly-healed flap; the blush extended, septic encephalitis set in, a fungus cerebri displaced the flap, and he died on the following day.

The autopsy was conducted by Dr. Newton eighteen hours after death with the following result :

(1) Purulent meningitis and encephalitis; fungus cerebri. Cyst well organized, polished, one and three-quarters inches deep, and from three-quarters to one and a quarter inches wide, extending through all the layers of the gray matter. No bullet was found in or about the cyst. All other parts of the brain examined and found to be healthy, save for the encephalitis.

(2) The brain was removed and the cranial bones minutely examined for entrance and exit of the bullet. The location of the scar upon the face indicated the original point of passage of the bullet, but no trace of entrance into the cranial cavity could be found. Every portion of bone was most scrupulously scanned, but no trace of the previous injury could be discovered. All the natural foramina were plugged, and the ether and light test applied. *All this proved negative; absolutely no evidence of the bullet ever having emerged from or entered the cranial cavity was present.*

Gunshot injuries of the facial region, the shot being fired from below and passing through the accessory sinuses may reach the cranial cavity, or they may stop short of this. In a case occurring in my own practice a boy was shot by a playmate, the bullet entering the antrum of Highmore. It was deflected from its course by impinging upon the lower margin of the orbit, and finally lodged in the sphenomaxillary fossa, where it was located by the telephone probe and removed.

Having positively determined that the bullet has perforated the skull, the next point to determine, if possible, is as to whether or not the dura mater has been perforated. The removal of a button of bone by the trephine, when the vault is involved, or enlargement of the original opening in the bone by the chisel and mallet, or Luers's cutting forceps, after preliminary shaving of a large area of the scalp and a proper disinfection of the surroundings, should be done preliminary to further search. The bullet may be found resting upon the dura, or between the dura and the inner table of the skull at the site of the wound, or at a point more or less remote from the original point of entry. This may occur in the case of a spent ball, or one which has lost its

projectile force immediately after entering the skull. In this connection an interesting case is related by Saxer.<sup>1</sup>

A soldier was struck by a musket-ball behind and above the left ear. He stated that the surgeons had probed for the ball, but it could not be felt. The wound remained open and suppurating for twenty years, the man complaining of pain and weight in the side of the head. He was frequently mentally deranged. He died of phthisis forty-three years after the injury. On autopsy the bullet was found to have entered the cranial cavity and to have turned sharply downward, lodging between the dura and the skull. The dura was closely adherent to the bullet; the latter had an irregular bony deposit about it.

The fact that a bullet may be fired from a weapon of good size, penetrate the skull, and yet not pass through the dura, is illustrated by a case reported by Bradford.<sup>2</sup> The bullet entered the parietal region, passed completely through both tables, made a half revolution upon its long axis, and was found lying with its butt-end upon the dura; it had not wounded the latter. In this case the bullet could not be found by the probe passed through the opening in the skull, but was discovered after trephining.

The dura mater may be injured by the splintered fragments of the inner table, the latter being driven into the substance of the brain, the bullet assuming an extra dural location. Walker<sup>3</sup> reports a case of this kind in a suicidal pistol-shot wound of the parietal region. The patient was promptly trephined and the ball and bone fragments removed. The wound was completely healed in nineteen days, the patient making a good recovery.

The ball may pass but a short distance into the brain substance and be identified by the surgeon's disinfected finger after trephining, the opening in the dura being enlarged for this purpose. Poirier<sup>4</sup> has reported the case of a boy, aged fourteen

<sup>1</sup> *Correspondenzblatt für schweizer Aertze*, Basel, September 15, 1891.

<sup>2</sup> *Boston Medical and Surgical Journal*, December 2, 1891.

<sup>3</sup> *Medical and Surgical Reporter*, Philadelphia, August 23, 1890.

<sup>4</sup> *Medical Press and Circular*, London, July 13, 1892.

years, who shot himself in the left temple with a revolver. The skull was freely opened up at the point of entry the same evening, and the finger passed into the lateral ventricle detected the ball. It was removed and the boy made a rapid and, according to the report, complete recovery. In those cases in which the bullet passes but a short distance into the cerebral mass after perforating the skull and dura mater, and in which the velocity of the ball has been, to a great extent, lessened by its passage through the outer table, the splintering of the internal table seems to be greater than where the clean "punching" effect of a ball with high velocity is exhibited. Wills<sup>1</sup> relates the case of a patient in whom the penetration of the cerebral structures was comparatively slight, but a number of fragments had been driven in and were removed, as well as the ball. The patient, although conscious, was not given an anæsthetic. He recovered. In connection with this question the experiments of Delbet and Dagron<sup>2</sup> upon the conditions found in self-inflicted wounds, are of interest. These observers found, in nineteen out of forty-five cases of experimental shot-wounds at short range, that splinters of bone were carried in with the ball and scattered in the brain substance.

When both tables are broken, the greatest amount of damage is inflicted upon the inner table; this is according to "Teevan's law," that the fracture commences in the line of extension rather than in the line of compression. That this is not due to the greater brittleness of the inner table, as formerly supposed, but rather to the fact that the internal table receives the force of the bullet, plus the force conveyed by the outer to the inner table, is shown by the fact that, when the vulnerating force is applied from within, the outer table is the one that is most extensively splintered.

The ball may be found within the dura, and below the point of entry. Lamphear<sup>3</sup> operated upon a man who was shot one inch to the right of the median line, and one and three-fourths of

<sup>1</sup> Medical Bulletin, Philadelphia, February, 1892.

<sup>2</sup> Bulletin de la Société anatomique, Paris, June 12, 1891.

<sup>3</sup> Kansas City Medical Index, August, 1888.

an inch above the supra-orbital notch. A probe could be introduced three and three-fourths inches without difficulty. He was trephined after twenty-six hours, but the bullet could not be found until the wound in the dura had been enlarged, when it was discovered about three-fourths of an inch below the point of opening.

The question of the direction which the projectile may have taken in cases of deep penetration of the cerebral mass should receive careful consideration before attempts at locating the same, either with the finger or probe, are made. A ball, after passing through the vault of the skull, may lodge (1) in the substance of one of the hemispheres; (2) it may traverse both hemispheres and lodge at the opposite wall of the skull; (3) it may traverse both hemispheres and, reaching the opposite wall without force enough to penetrate it, turn back and after a recurrent course of from one to three inches lodge in the brain substance; (4) it may pass clear through (perforating gunshot injuries). As a further result of the experiments by Delbet and Dagrón, above alluded to, it was shown that the direction of bullets entering the temporal region in suicidal cases may be such as to give rise to motor symptoms. The motor centre, situated highest and farthest back, is more likely to be injured, the ricochet being in that direction,

The probable direction of the ball, based upon the position which the fire-arm was held at the time of the shooting, should always be taken into consideration. Likewise, a thorough inspection of the opposite side of the head should be made for here, as in the case of shots fired from the direction of the cavity of the mouth, a perceptible bulging or other evidences of a fracture may be found at a point opposite the wound of entrance. Even the primary course which a ball takes after entering the cavity of the cranium must always remain uncertain, and the difficulties which surround the diagnosis are further enhanced by the fact that the ball may strike the opposite wall, become deflected at a greater or less angle, and finally lodge at a point remote from the line of its original passage. Fluhrer,<sup>1</sup> in 1884,

<sup>1</sup> New York Medical Journal, March 28, 1895.

reported a case in which he made a second trephining at the point of impact against the opposite wall, in order to trace the secondary course of the deflected ball.

In connection with the subject of rebounding of missiles from fire-arms and repenetration of the brain from these in pursuing a secondary course, it may be observed that Ruth<sup>1</sup> disagrees with Fluhner's statement that the bullet may be deflected after passing through the brain and impinging upon the opposite side, and asserts that a ball will only rebound when flattened at least one-third, and that a velocity that will produce this amount of flattening will be almost certain to produce penetration of the skull at the point of impingement. According to this observer, if the ball strikes at right angles to the surface, or within fifteen degrees, and does not penetrate, the ball will be far more likely to lodge at the point of impact or very near thereto than to rebound. Repenetration, after striking the opposite wall of the skull occurs, according to Ruth, but rarely, and when deflection does occur, it is almost invariably at angles of more than ninety degrees to the angle of incidence.

The first attempts to search for the bullet in cases of complete penetration—*i.e.*, where both bone and dura have given passage to the ball—will consist of an exploration, by means of the finger, of the lacerated brain substance in the immediate vicinity of the wound in the dura. This may reveal the presence of splinters of bone, even if the ball itself is not located, and lead to the removal of these and prevent further mischief arising from their presence during the subsequent manipulation. Failing to identify the missile in this manner, the surgeon will at once consider the question of probing the brain. In this manipulation the greatest judgment is necessary, as is also the employment of the most delicate touch. A sharp-pointed instrument should never be employed, nor yet one of the pocket-case probes, which almost always find a place in the every-day emergency equipment of the surgeon. The search should be proceeded with deliberately, and only after full and complete ante-operative precautions of an aseptic character. The probe itself may be of any metal, but of

<sup>1</sup> Journal of the American Medical Association, August 20, 1892.

whatever material made it should consist of a spherical or olive-shaped tip, mounted upon a slender shaft in order to minimize the friction in its contact with the collapsed bullet track and insure that all the resistance to be appreciated by the hand manipulating the probe is communicated from its tip. The amount of pressure to be employed consistent with safety will necessarily vary with the size and shape of the olive-shaped or spherical tip, the smaller and more wedge-shaped tip easily leaving the bullet track and passing between adjacent convolutions or into the brain tissues. For this reason the character of the weapon from which the shot was fired should be ascertained, if possible, and its calibre noted, in order that a proper-sized probe-tip may be selected for the particular case. A tip one-quarter inch in diameter will usually answer for any bullet from a .32-calibre up, and a three-sixteenths one will follow the track of a bullet from one of the smaller fire-arms. The amount of force to be employed, within the limits of safety, in propelling a probe along the supposed track of the bullet has been studied by Ruth,<sup>1</sup> who concludes as the result of his experiments that a probe-tip one-quarter inch in diameter requires from two and a half to three ounces weight to penetrate normal cerebral tissue, and from one and three-fourths to two ounces to cause it to pass between the convolutions. If smaller tips are used, the force must be proportionately lessened, but it will rarely be necessary to use a probe of less than three-sixteenths of an inch in diameter, which will require from one to two ounces pressure to penetrate normal brain tissue. The practical application of these experiments of Ruth would consist of either a device whereby the exact pressure in ounces, exercised at any time during the manipulation, could be seen at a glance, or the preliminary application of weight to the instrument, the surgeon depending upon the force of gravity alone to carry it along the bullet track to the termination of the latter at the site of the missile. The first would involve the use of a coiled spring which would first receive the pressure, and a graduated index to record the latter.

Such an instrument has been constructed at my suggestion

by Tiemann & Co., of New York (Fig. 1). It consists of a slender stem with an insulating covering of rubber designed to prevent error in locating the missile arising from contact with portions other than the tip. The stem has a bulbous tip which is designed to follow the track of a bullet from .22-calibre and upward. The handle is of hard rubber, is hollow, and slides upon the stem against the pressure of a spiral spring which surrounds the latter. The portion of stem seen projecting beyond the handle is for the attachment of the telephonic probe apparatus. An indicator upon the stem and a scale marked in fractions of an ounce upon the handle record the exact amount of force which is being exerted upon the probe within the limits of the compressibility of the spring. The latter is so arranged that it is within the safe boundaries prescribed as the result of Ruth's experiments. The upper extremity of the handle is made to unscrew for the purpose of cleansing.



FIG. 1.—The graduated pressure brain probe.

The probe is to be used in the horizontal position, in order that the question of weight of the instrument and gravity need not enter into the consideration. The cord attachments connecting it to the telephonic apparatus should be made of aluminum, and be as flexible as possible in order to avoid embarrassment of the operator's manipulations by the weight or awkward movements of the cord. After trephining the skull and enlarging the opening in the dura the tip of the probe is introduced and passed in the supposed direction of the bullet. As long as the pressure made is within the limits of the spring, as shown by the indicator and scale, the probe is in the bullet track. As soon as the tip leaves the path of the missile this will be shown by an amount of force necessary to propel it forward beyond that which is necessary to compress the spring. In other words, as long as the surgeon is making pressure upon the probe with the spring intervening he is within the limits of force necessary to push the tip of the probe into the cerebral tissue or

between the convolutions. As soon as the index shows that the compressibility of the spring has been overcome, or even when the limit of this has been almost reached, the probe is to be withdrawn for a short distance and another attempt made to follow the bullet track. The probe will not leave the latter without first giving warning by means of its indicator and index. Contact with the bullet or fragments thereof will be announced by the characteristic click in the telephonic receiver applied to the ear.

Attempts have been made to locate the exact position of the bullet in its relation to the surface and to indicate the exact point at which a counter opening may be made by the trephine. Morgan's<sup>1</sup> instrument consists of an inflexible meridian whose distal pole corresponds to the point of the proposed exit wound when the proximal pole is placed upon a properly introduced searching probe. The trajector is made of a solid bow of steel, in the end of which is a movable rod. The opposite end is arranged so as to adapt itself to any sized probe. A gravity probe is employed, and this is allowed to follow the bullet track until the depth and direction of the latter are ascertained, when it is steadied in position, the trajector placed upon it, and the movable rod pushed along it until it touches the scalp. The proper point for the application of the trephine will be indicated by the point.

Although a white porcelain tip whose surface is slightly roughened, in order to receive the markings of a lead ball, has been in use for many years, this is far inferior to the device known as "the telephone probe," for the introduction of which the profession is indebted to Dr. Girdner, of New York. With the improvement of probes insulated at all parts except the tip, in order to avoid the fallacy arising from contact of the shaft instead of the tip, and an arrangement whereby the receiver may be fastened to the head of the surgeon, instead of being held in the hand, both of which were suggested by myself in a paper presented at the meeting of the Association of Military Surgeons, held in Chicago, August 8, 9, and 10, 1893,<sup>2</sup> added to the fact

<sup>1</sup> Indiana Medical Journal, September, 1892.

<sup>2</sup> Transactions of the Association of Military Surgeons of the United States, St. Louis, Mo., 1894.

that the telephone receiver of Graham Bell is no longer protected by a patent, should lead to the substitution of this instrument for the old porcelain probe in the armamentarium of every surgeon. In the German army the telephone probe is a part of the field equipment of the medical corps.

It has been erroneously supposed that the telephone probe is complicated, and requires a battery for its operation. Nothing could be further from the truth. It simply involves the proper attachment of the connecting wires, and care that these do not come in contact with anything that will produce grating or clicking sounds, which, communicated to the receiver and thence to the ear of the operator, might interfere with a proper appreciation of the characteristic sound which announces the fact of contact of the probe with a metallic surface in the tissues. This peculiar sound will never be heard when the probe comes in contact with substances other than metal, of whatever nature these latter may be. This sound once heard will always be recognized and cannot be mistaken for anything else. No battery is required, and there is no complicated apparatus to get out of order or need adjustment. The principle upon which it is constructed is absolutely correct, and its application simplicity itself.

Finally, search for the bullet by means of a long, slender blunt needle passed through the cerebral substance, avoiding the sinus of the dura and the medulla, has been employed, although without success up to the present time. The toleration of the brain to this manipulation has been shown,<sup>1</sup> but the method involves too much risk for general application.

## II. THE REMOVAL OF MISSILES FROM THE CRANIAL CAVITY.

The large majority of those shot in the head upon the field of battle die upon the field, and never come under the surgeon's observation. This is particularly true of rifle-ball wounds of the head, the immediate mortality from which is very high, and which constitute by far the great majority of cranial fire-arm wounds received in active service. In civil practice, pistol-ball wounds

<sup>1</sup> Brooklyn Medical Journal, June, 1888.

predominate, and instant death is not so common but that almost every hospital surgeon, and many engaged in private practice alone as well, must meet with this class of injuries from time to time.

The large number of cases in which recovery has ensued without operation in bullet-wounds of the cranial cavity, particularly in cases of pistol-shot wound, on the one hand, and the generally supposed comparative infrequency of recovery in cases in which operative interference is instituted, on the other, seems to have thrown some doubt upon the justifiability of surgical intervention in this class of cases. Differences of opinion exist, therefore, as to the indications for operative interference other than the turning back of a flap of the scalp and trephining for the purpose of removing splinters of bone and the bullet as well, if within easy reach. Bearing upon this point the studies of Huhn<sup>1</sup> are of interest. This observer reported 423 cases of foreign bodies in the brain, of which 199 died and 224 recovered. Of the 199 fatal cases, the foreign body was removed in 48; in the remaining 151 cases the foreign body remained in the brain. A larger mortality percentage was found in cases where operative interference was not resorted to, as shown by the following figures:

Fatal cases . . . . .	199.
Body removed in . . . . .	48, or 24.2 per cent.
Body not removed in . . . . .	151, or 75.8 per cent.
Non-fatal cases . . . . .	224.
Body removed in . . . . .	113, or 50.4 per cent.
Body not removed . . . . .	111, or 49.6 per cent.

(In these cases the figures in removal and non-removal cases are about equal, and give results slightly in favor of removal.)

The mortality differs in different regions of the brain, according to Huhn, as follows: In the anterior cerebrum the mortality was 38.5 per cent.; in the middle cerebrum the mortality was 41.5 per cent.; in the posterior cerebrum the mortality was 43 per cent. Foreign bodies in the cerebellum invariably proved fatal.

<sup>1</sup> University Medical Magazine, May, 1892.

The above statistics refer to foreign bodies in general. Limiting the inquiry to cases of bullets in the brain, it was found that, of 286 cases, 143 cases recovered and 143 died, a mortality of exactly 50 per cent.

Studies by Huhn directed to the question of the removal of the bullet gave the following result:

Non-fatal cases . . . . .	143.
Bullet removed in . . . . .	56, or 39.1 per cent.
Bullet not removed in . . . . .	87, or 60.9 per cent.
Fatal cases . . . . .	143.
Bullet removed in . . . . .	112, or 78.3 per cent.
Bullet not removed in . . . . .	31, or 21.7 per cent.

Of 168 cases operated upon, including cases in which the bullet was removed, as well as those in which it was not, 112 died and 56 recovered, showing a mortality of 66 or  $\frac{2}{3}$  per cent. Of 118 cases not operated upon, 87 recovered and 31 died, showing a mortality of 26.3 per cent.

Since the introduction of aseptic and antiseptic surgery, 60 cases have been reported, of which 24, or 40 per cent., died and 36, or 60 per cent., recovered. The question of removal or non-removal under aseptic and antiseptic treatment shows a decided gain in favor of the former above the figures previously quoted, as follows: number of cases occurring in the aseptic and antiseptic era, 60. Bullet removed in 24 cases, with a mortality of 16, or  $\frac{2}{3}$  per cent. Bullet not removed in 36 cases, with a mortality of 59, or  $\frac{4}{5}$  per cent.

Huhn further studied the question of the mortality of cerebral abscess following foreign bodies in the brain. These all occurred in pre-antiseptic times and gave a mortality of 91 per cent.

According to Bradford and Smith,<sup>1</sup> when the bullet perforates (both entering and emerging) or is removed, the mortality is but 33.3 per cent. When it lodges or remains it is 54 per cent.

Commenting upon these figures, Bradford and Smith say, "These results are what would be expected, since, generally

<sup>1</sup> Boston Medical and Surgical Journal, October 15, 1891.

speaking, those bullets are removed by means of the trephine which have passed but a little way into the brain, the damage to the cerebral substance being slight and the ease and thoroughness of drainage far greater."

The recent literature of gunshot-wounds of the head is replete with instances of so-called recovery, in spite of the presence of the bullet. (Somers,<sup>1</sup> Park,<sup>2</sup> Corniere,<sup>3</sup> Mouchet,<sup>4</sup> Johnston,<sup>5</sup> Oetman, Jr.,<sup>6</sup> Wyman,<sup>7</sup> Winne,<sup>8</sup> Wheaton,<sup>9</sup> Cullen,<sup>10</sup> Cooge,<sup>11</sup> Drzewicki,<sup>12</sup> and Radejewski, reported by Barry.<sup>13</sup>)

The use of the word "recovery" requires a passing notice in connection with those cases in which the missile remained in the cranial cavity, and the patient is reported as recovered. Experience seems to show that, although there may be a subsidence of the symptoms, the presence of a foreign body in the brain must be regarded as a constant menace to the patient. The word "recovery," therefore, in this connection, should be used only with reference to the immediate result following the injury. Cases not uncommonly come under the surgeon's notice which have been previously reported as cured, in which the fallacy of hopes based upon an early subsidence of the symptoms is illustrated. The following case, reported by Colquhoun,<sup>14</sup> may be related in illustration :

Four years previously, the patient, then a young man of twenty, had shot himself in the head with suicidal intent. The ball was not removed, and the patient was reported as having made a good

<sup>1</sup> Occidental Medical Times, Sacramento, April, 1892.

<sup>2</sup> Medical News, Philadelphia, December 3, 1892.

<sup>3</sup> Bulletin de la Société anatomique, December, 1892.

<sup>4</sup> Bulletin de la Société anatomique, February, 1893.

<sup>5</sup> Montreal Medical Journal, March, 1893.

<sup>6</sup> China Medical Missionary Journal, Shanghai, March, 1893.

<sup>7</sup> Detroit Emergency Hospital Reports, March, 1893.

<sup>8</sup> North Western Lancet, St. Paul, Minn., April, 1893.

<sup>9</sup> North Western Lancet, St. Paul, Minn., April, 1893.

<sup>10</sup> The Lancet, London, June 24, 1893.

<sup>11</sup> Southern Medical Record, Atlanta, Ga., August, 1893.

<sup>12</sup> Annual of the Universal Medical Sciences, Vol. III, 1893, Section A, p. 36.

<sup>13</sup> Hot Springs Medical Journal, January 15, 1893.

<sup>14</sup> Gazette des Hôpitaux, Paris, January, 1890.

recovery. Later on he was subject to epileptiform convulsions, and became fickle, erotic, devoid of self-control, and unfit for work. When seen by Colquhoun he was unconscious, and in convulsions almost constantly. These latter continued with but slight intermissions, until he died, three days later. The autopsy showed a ragged and flattened bullet embedded in the inner table of the skull near the middle line in front, having traversed the brain substance, damaged several of the convolutions, impinging upon the inner table from within, and producing a fracture, as shown by a bony growth and adhesions between the brain, dura mater, and skull at this point.

One of the most remarkable cases, in which a foreign body remained in the brain for a long time without giving rise to serious symptoms, in the literature of the subject is related in the *Medical Press and Circular*, January 18, 1895, as follows:

A man entered the London Hospital complaining of pain in the head and drowsiness. He died suddenly a few days later, with symptoms of apoplexy. The post mortem revealed an abscess at the base, inside which a pen-holder and nib, measuring nearly three inches in length, were found. The nasal cavities and corresponding eye were carefully examined, but no trace of injury to these parts could be discovered to show the manner of entrance of the foreign body into the cavity of the cranium. The man was thirty-three years old, had been married a number of years, but the widow had never heard him allude to any injury which could account for the presence of the pen-holder and nib.

At a meeting of the Brooklyn Surgical Society, held February 2, 1888, there was related the case of a lad who had been injured by a missile from a ten- or twelve-inch toy cannon. The missile, a stone, was as large as an almond, and entered the cavity of the cranium just above the groove for the right lateral sinus. An exploratory trephining was done the next day, but the foreign body was not found. The operator, in concluding the narration of the case, remarked, "He lived some eight or ten years and then, finally, died of tuberculosis of the lung; he made good progress in his studies, and was a bright, active business lad." While it is true that this boy was bright and active,

it is also true that he came under my observation not less than three years before his death for Jacksonian epilepsy, but operative interference was declined by the parents. The next information I had concerning him was the announcement of his death, several weeks before, from pulmonary tuberculosis.

In another class of cases the occurrence of symptoms from which apparent recovery takes place, but in which one or more relapses occur, with a final fatal issue, is illustrated in the following cases :

Froelich<sup>1</sup> relates the case of a student, aged twenty-one years, who came under his observation in an unconscious condition, with a revolver wound of the right temple. Search for the bullet proved unsuccessful, and he was discharged at the end of three weeks, apparently well, save for loss of vision in the right eye. Nine months afterwards he was attacked with violent pains in the head and died in coma on the nineteenth day. At the autopsy it was found that the bullet had entered the orbit, tearing away the optic nerve in its passage, and lodged on the under surface of the orbital plate of the frontal bone, where it was found embedded in a mass of callus. The entire base of the brain, on both sides, medulla oblongata, and upper portion of the spinal cord were bathed in pus ; the ventricles were full of purulent fluid.

Battle<sup>2</sup> reports, among other cases, that of a boy who received a bullet wound of the skull from a small revolver. The wound of entrance was two inches above and one and one-half inches in front of the left auditory meatus. Double optic neuritis occurred, and on the third day an exploratory trephining was done, but the bullet was not found. The neuritis slowly improved until recovery apparently took place, and a fungus cerebri, which had developed in the meanwhile, disappeared. He was kept under observation at the hospital for four months, however, and was then discharged. Four weeks later epileptic seizures came on and he was readmitted ; five weeks later the optic neuritis had again developed. He died about nine months from the time of the injury. The autopsy showed a thick-walled abscess cavity. The bullet was found low down in the right frontal lobe, at some distance from the abscess cavity, and surrounded

<sup>1</sup> Münchener medicinische Wochenschrift, August 25, 1891.

<sup>2</sup> British Medical Journal, July 12, 1890.

by apparently healthy white cerebral tissue. There was no track to show the course the bullet had taken to reach this spot.

In debating the question of the advisability of a thorough search for and removal of missiles from the cranial cavity, the additional damage which this will inflict upon the brain is to be taken into account. The surgeon should bear in mind the fact that, with the exception of cases in which the ball has passed through the brain and lodged in the bone of the opposite wall of the skull, from which it has been removed by a counter-opening, and those in which it has passed but a short distance into the cerebral tissues and has been found to be readily within reach, as well as those instances where it has lodged between the dura mater and the skull, the location and successful removal of a missile from this region is of rare occurrence. On the other hand, it may be said, as stated by Bradford, that "the general surgical instinct which prompts attempting whatever offers a possibility of success in cases where death seems certain," will favor operative interference, with the view of the removal of the bullet.

In any event there can be no two opinions as to the necessity for (1) shaving the scalp far and wide of the opening of entrance and also that of exit; (2) scrubbing, with a stiff brush and soap and hot water, of the entire head; (3) disinfection of the external parts by means of a mercuric chloride solution, or some trustworthy germicidal antiseptic; (4) turning back of a flap of scalp to thoroughly expose the wound in order to furnish sufficient room for subsequent manipulation, and to provide for drainage; (5) enlarging the opening in the dura, which is usually smaller than the bullet, in order to turn out clots, facilitate the search for and removal of splinters, as well as the bullet itself, and afford drainage to the lacerated brain substance. Further operative treatment, which has the sanction of many practical surgeons of the present day, consists in (6) making a counter-opening in the skull in cases in which the bullet can be traced at a point more or less remote for the purpose of making further search for and removing the bullet, treatment of a fracture, and providing through-and-through drainage.

In this connection it is interesting to note Von Bergmann's<sup>1</sup> remarkably conservative opinion, in view of the operative boldness which has characterized German surgery since the advent of aseptic and antiseptic wound treatment. He declares that in shot-wounds of the skull the wound should be closed, exactly as in wounds of the knee-joint, and protected against further injury. When no symptoms are present, no operative interference is necessary; but immediate and severe symptoms of irritation, such as contractions, epileptiform convulsions, monoplegia, etc., justify operation. If, however, the symptoms of irritation occur later, trephining is not advised.

Having trephined the skull in such a manner as to include in the trephine-opening the wound in the bone, and to afford an opportunity for the removal of the *débris* from the scalp, hair, etc., and, perhaps, wadding from the cartridge, and located the



FIG. 2.—Showing the comparatively small amount of space required in using the newer pattern of bullet-forceps, with double joint.

bullet, the latter is to be grasped by some form of forceps and removed. Where the missile lies between the dura and the skull, this can usually be effected with the thumb-forceps, hæmostatic forceps, or a curette or small scoop. If it lies in the cerebral substance and can be detected by the finger, these means are also applicable. Where, however, it lies at a greater depth, some one of the specially designed bullet-forceps will be required. Of these several models are made by the instrument-makers, the one best adapted for the purpose is that known as the Tiemann double-jointed bullet-forceps (Fig. 2). While under ordinary circumstances there is no particular objection to the stretching of the bullet track, which the opening of the jaws involves in the use of the ordinary bullet-forceps (Fig. 3), this becomes a matter of

<sup>1</sup> Münchener medicinische Wochenschrift, June 27, 1893.

great importance when the manipulations are made along a track which leads through brain substance. Here every impingement by the forceps upon the wall of the channel made by the bullet may, and generally does, mean fresh injury to the cerebral tissues.

Where the telephone probe apparatus is at hand, the electric bullet-extractor, devised by Medical Inspector Wells,<sup>1</sup> United States Navy, may be employed. This is attached to the connecting wire in place of the probe, and announces by the characteristic click heard in the receiver when the instrument is in contact with the missile, if the latter be of metal. The special model of bullet-extractor, which has been selected for this application of Dr. Girdner's principle by Dr. Wells, is such as to permit of its use without the electrical attachment.

While performing the necessary movements in the extraction, these should be as gentle as possible. Rapid withdrawal of



FIG. 3.—Showing the increased space necessary, and consequent compression of brain tissue in extracting a bullet from the brain with the old-fashioned bullet-forceps.

the missile is neither necessary nor desirable; a sudden jerk of a ball roughened by its passage through the rifled bore of a modern fire-arm, or more or less flattened by its passage through the bone at the wound of entrance or against the bony wall of the opposite side of the skull, may inflict almost, if not quite, as much damage upon the cerebral tissue in the withdrawal as in its original flight.

While the use of the ordinary mercuric chloride solutions is permissible for purposes of disinfection in all extradural injuries, even the weakest solution of this agent, or even carbolic acid, is to be avoided when the cerebral substance is exposed. Adamkiewicz<sup>2</sup> has shown by experiments upon dogs that the weakest

<sup>1</sup> Medical Record, New York, January 5, 1895.

<sup>2</sup> Deutsche medicinische Wochenschrift, January 12, 1893.

solutions of these (1 to 10,000 of the first and 1 to 200 of the last named) of any service for the purposes of asepsis or antiseptis, produce deleterious effects upon the brain substance, particularly when this is lacerated. It therefore becomes necessary to substitute either simple sterilized water, a sterilized normal salt solution (6.5-per-cent. solution: Tavel), or, at the most, a 3-per-cent. boric acid solution (Adamkiewicz), made with sterilized water, for the stronger irrigating fluids.

The arrest of hæmorrhage is of importance in gunshot wounds of the brain,—so much so that operative interference is justifiable from this point alone, irrespective of the removal of the missile. In Bradford and Smith's statistics, out of fifty-nine cases, death was caused by hæmorrhage in ten where no operation was performed, and in but three cases where an attempt was made to remove the bullet. The importance of arresting hæmorrhage relates, however, not so much to the threatened loss of life from actual loss of blood, as to those dangers that may arise from increasing pressure of blood poured out within a cavity with unyielding bony walls. This latter, while it serves to limit the bleeding within the danger-point of death from hæmorrhage, may, from its pressure effects, increase the shock, and, by inducing degenerative or destructive changes in nerve substance, lay the foundation for future mental impairment in cases which otherwise recover.

After enlarging the wound in the dura, if any vessels in this structure are found to be bleeding, they may be caught up with hæmostatic forceps and ligated. All clots and devitalized tissue having been removed from the bullet track by irrigation and the gentle use of a scoop, the bleeding will frequently be found to have ceased; if not, a tampon of iodoform gauze is to be carefully introduced into the opening in the brain or against the lacerated surface. The amount of gauze which can be introduced without of itself producing pressure symptoms is considerable. The gauze should be applied in the shape of a narrow continuous strip, which has been doubled in its lengthwise direction with the edges turned in at the middle, and secured by a line of stitching. The object of this is to prevent the strip from fraying and leaving

threads of the gauze behind in the brain upon withdrawal of the tampon.

The occurrence of severe and persistent hæmorrhage, as shown by the appearance of the blood from the wound through the tampon, or progressive increase in the compression symptoms may be met by ligation of the carotid artery. Secondary hæmorrhage due to changes in and about the wound arising from septic infection is to be treated by ligation of the bleeding vessel, or this failing from inaccessibility of the latter, or the impossibility of getting a ligature to hold upon softened tissues, ligation of the external carotid, if the bleeding is from one of its branches. Experience shows that this is a safer operation than ligation of the common carotid and more effective in controlling the hæmorrhage.

Drainage is to be effected by means of strips of gauze while bleeding is in progress, and by soft rubber drainage-tubes when there is no hæmorrhage. The tube may be made to pass entirely through in those cases in which perforation takes place. Otherwise its introduction for a distance of an inch from the wound in the dura will serve the purposes of drainage.

The external wound is to be closed completely except at the point where the drainage-tube passes out. An aseptic dressing is applied and held in place by a roller bandage which should include the entire head, particular pains being taken to include the occiput low down; a few turns should pass beneath the chin. The restlessness of the patient will sometimes necessitate the application of a plaster-of-Paris bandage over all.

The patient is to be placed at absolute rest and kept upon a light but nutritious diet. Stimulants may be given if absolutely necessary. If a rise of temperature occurs, it is probably due either to septic meningitis or infection of the external parts. In case encephalitis develops and is not controlled by removal of the dressings and careful cleansing, it is recommended to bleed from the jugular vein (Huhn).